Architecture Image Studies
AIS Scientific Journal

Vol.6, Issue 3, pp.966-979, 2025
DOI: https://doi.org/10.62754/ais.v6i3.356

https://journals.ap2.pt/index.php/ais/index

Designing Physical Learning Environment for Restrictive and Repetitive Behaviors in Children with Autism

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Abstract

Restrictive and Repetitive Behaviors (RRBs) are the most prominent problematic characteristics in children with autism. Neurophysiological studies indicate that environmental stimuli are the main triggers of RRBs, making the physical environment crucial for managing RRBs and enhancing these children’s participation in daily activities. However, standardized guidelines for designing autism-friendly learning environments to address RRBs remain lacking.This quantitative study used a survey method to explore the relationship between RRBs in autistic children and physical learning environment design. A total of 100 participants were involved, with data entered and analyzed via SPSS; Pearson’s correlation coefficient was used to examine variable relationships. Results show a significant, close association between RRB severity and physical learning environment design. These findings are expected to provide useful references for optimizing autism learning environments in China.

Keywords: *Children Learning Environment; Autism Spectrum Disorder; Repetitive Behaviour; Restrictive Behaviour; Artificial Intelligence.*

Introduction

A recent multicenter population study estimated the prevalence of ASD among children aged 6 to 12 in China to be approximately 0.70% (Song et al., 2022). Due to insufficient public awareness of ASD and parental reluctance to report atypical child development due to social prejudice, the actual prevalence may be as high as 1%, especially in rural areas (Wang et al., 2020). Restrictive and Repetitive Behaviors (RRBs) represent an important yet reversible negative trait in Autism Spectrum Disorder (ASD). These behaviors emerge in response to minor changes in daily routines or unfamiliar situations, reflecting individuals' attempts to reduce subjective arousal, cope with unfamiliar contexts, and maintain a sense of familiarity (Russell et al., 2019). For example, nail-biting, thumb-sucking, and hair-twisting are common RRBs that are generally harmless and even observed in neurotypical individuals, particularly under stress or anxiety. In contrast, complex RRBs such as head spinning, flapping, arm waving, finger flicking, and body rocking are more strongly associated with ASD and are typically regarded as problematic (Tian et al., 2022). Given that the physical environment serves as a critical stimulus influencing children's behavior, these insights must inform the design of ASD-friendly physical environments to mitigate RRBs (Norouzi & Garza, 2021). Furthermore, to ensure the effectiveness of early intervention programs for ASD, which require at least 25 hours per week, the learning environment becomes an ideal "out-of-home" early intervention tool for addressing RRBs, as children spend most of their time there (Tola et al., 2021). The physical environment has emerged as a key pathway for treating various health issues, including depression, anxiety, and behavioral disorders (Mostafa, 2014; 2018; Shaari et al., 2020a). However, standardized architectural design guidelines for Autism Spectrum Disorder (ASD) remain absent (Clouse et al., 2019). This study aims to explore the

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relationship between the physical learning environment of classrooms and repetitive behaviors in children with ASD, with the further goal of identifying criteria that demonstrate a strong and significant association between physical learning environments and repetitive behaviors. The findings are expected to foster conducive learning environments for children with ASD and provide a design benchmark for technical and relevant government agencies to improve ASD learning environments in parts of China.

Literature Review

This paper reviews built environment studies and its impact on childhood ASD behaviours. It aims to improve understanding of various design aspects on ASD behaviour and analyze how they can affect RRBs. Electronic databases (Google Scholar, Science Direct, Scopus, and Web of Science) were searched with the keywords “learning environments” AND “autism spectrum disorder” from 2014 to 2024. When analyzing the influencing factors of physical environment design on repetitive behaviors in preschool children with autism, it is first necessary to clarify the specific meaning of autistic repetitive behaviors. This review aims to systematically review and evaluate existing studies, covering multiple aspects of interventions for repetitive behaviors in children with autism.

Review of repetitive behaviors in autism

RRBs are an important detrimental but reversible feature of ASD. RRBs refer to diverse observable motor sequences that exhibit characteristics such as rigidity, invariance, inappropriateness, and purposelessness (Russell et al., 2019). These behaviours can manifest when there are slight changes in routine or in the presence of unfamiliar stimuli, by which a person will aim to decrease subjective arousal and cope with unfamiliar events in order to maintain a state of familiarity (Russell et al., 2019). RRBs are often divided into two types - common and complex RRBs (Raya et al., 2020). Nail-biting, thumb sucking, and hair twirling are examples of common RRBs which are often harmless and can even be seen in normal people, particularly in situations that induce stress or anxiety. Complex RRBs such as head spinning and banging, arm flapping, finger wiggling, and body rocking are more commonly associated with ASD are those that are often regarded as problematic (Tian et al., 2022). (Table 1).

Table 1. RRB Subtypes according to the DSM-5

RRB subtype	Characteristics
Ritualistic/sameness behaviours	Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or non-verbal behaviour
Compulsive behaviours	Excessive repetition of a particular movement to satisfy a compulsive need such as hand-washing, checking, and counting objects repeatedly, and/or silent repetition of prayers or phrases with no specific meaning
Stereotypical behaviours	Stereotyped motor movements, use of objects, or speech
Self-injurious behaviours	Abnormal aggressive behaviour resulting in significant pain or injury such as head-beating, hair-pulling, and skin picking
Restricted interests	Restricted interests with abnormal intensity or focus

Review of Physical Learning Environment design

A literature search on "autism" in CNKI shows that most research is concentrated in pediatrics, special education, psychology and medical disciplines. Under the discipline of architecture and engineering, a search with the keyword’s "autism" or "Asperger's syndrome" and "rehabilitation institutions/rehabilitation centers" yields 41 articles, including 25 dissertations, 14 academic journals and 2 conference papers. It can be seen that domestic theoretical research on autism mainly focuses on the medical, special education and psychological fields, concentrating on the etiological mechanisms and educational intervention methods for autistic children. Research in the architectural discipline is scarce, and studies on the spatial design of rehabilitation institutions are in their infancy. In terms of architectural space design, current domestic research mainly focuses on indoor space design and outdoor space design. In indoor space design, there are specialized design studies on color, walls and furnishings (Shaqour,2021; Association,2021). For instance, Wang Lin (2021) conducted research on the creation of a color environment in indoor spaces; Chen Xiao proposed design strategies for the furnishing design in current rehabilitation institutions for autistic children; Wang Mingyue et al. (2014) suggested that wall design should be combined with educational requirements to have a positive educational impact on children. Additionally, Wang Mengru(2021), Yang Ling(2015), Tang Fanting (2018), Chen Wan (2018), Lyu Wanrong (2020), and Su Mengxuan (2019) based their research on actual investigations, analyzing the location and scale, functional room composition, and space composition of current rehabilitation institutions for autistic children in China, and through their investigations, they discovered actual problems and proposed design principles and strategies. The classification basis for the proposed strategies is either space type or space design elements. Space types include living spaces, rehabilitation spaces, service spaces, and public spaces; space design elements include color, interface, furnishings, and physical environment. Many aspects of the physical learning environment deserve attention and discussion, such as building entrances, building scale, safety and security, personal space and activities, wayfinding, legibility, transition areas, classrooms, quiet rooms, restrooms, visual distractions, sunlight and glare, lighting, acoustics, smells, calm low-stimulus spaces, and sensory gardens. These elements together constitute a positive learning environment (Ghazali et al., 2019).

Physical Learning Environment as Early Intervention for RRBs in ASD

Conducting a comprehensive literature search in the database, I discovered an extensive body of research on autism encompassing medicine, psychology, sociology, and education. Interestingly, some literature labeled as 'environmental intervention' actually focused on providing toys or engaging in game activities (Spiel et al., 2022). However, there is a scarcity of literature specifically addressing the physical environment aspects such as space layout, flow organization, lighting, acoustics, color schemes, and furniture design (Godden et al., 2019). Furthermore, the availability of literature meeting evidence-based design criteria is even more limited. Consequently, due to this dearth of relevant studies available for review purposes in this field thus far (Babbie E R., 2020), our study incorporates a comprehensive qualitative research interpretation along with an experimental analysis literature review to provide profound insights. In summary, it is found that some evaluation items reflect more than one requirement. Some evaluation items reflect both the need for predictability and the need for sensory intervention. Therefore, some evaluation items will appear in both requirements.

Through the aforementioned research, it is concluded that autistic children have 10 specific spatial needs: acoustics, space sequencing, escape spaces, compartmentalization of space, sensory zoning of transitions, security needs, predictability, belongingness and social support (Ungar, 2021). In order to focus on repetitive behaviours in the indoor environment of children with autism and eliminate redundant and irrelevant items from consideration, the ASPECTSS seven elements guideline proposed by Magda Mostafa was ultimately adopted as a reference.

Table 2.Spatial requirements and meanings of autistic children (Mostafa 2018,2015, 2014; Dong, 2022)

Space requirement	Implication
Acoustics	This criterion calls for the reduction of internal and external noise sources through various means such as cavity walls, sound proofing and sound absorbent materials, spatial configuration to reduce echoes and isolation of sound emitting building systems and avoidance of sound-emitting fixtures such as fluorescent lighting(Amran et al., 2021).
Spatial Sequencing	The setting of spatial sequence refers to dividing the space into discrete units of small-scale activities and experiences, and organizing them according to the logic of sensory intensity, which can be easily predicted and controlled by the autistic group.This criterion calls for the alignment of the sequential organization of space and the daily routine of the users. This should be in a series of smooth transitions from one space to another, in a manner that follows the typical daily schedule of users, and allows for as seamless and sensory non-disruptive flow as possible(Unwin et al., 2021).
Escape Space	In the investigation of spatial sequences, Magda also established a crucial microenvironment within the experimental classroom known as the "escape space," strategically positioned in the least stimulating area. This designated sanctuary serves as a refuge for children who experience overwhelming sensory input(Unwin et al., 2021).

Compartmentalization	This criterion outlines the organization of spaces in a series of monofunctional compartments, allowing for single activities and smaller numbers of users(Unwin et al., 2021).
Transitions	The transitional space is one of the "seven elements Guiding principles" proposed by Magda Mostafa. While combining spatial order and sensory zoning, the presence of transition zones can alert autistic users to move from one stimulus level to another and help them recalibrate their senses (Bellamy et al.,2021).
Sensory Zoning	When designing for autism a slightly different approach is called for, requiring the organization of spaces in accordance with their sensory levels and qualities. Sensory zoning calls for the grouping of spaces with similar sensory stimulation levels together, into high, moderate and low stimulation zones. Transition spaces should be used between these zones, and circulation should be planned to follow the daily routine as called for by the spatial sequencing criterion(Ueno et al., 2019)
Safety	Safety considerations must be taken with all building systems, material choices, surfaces, protective barriers, furniture, fixtures etc. It is best that all spaces also be visually accessible to allow safe monitoring of children at all times.

Methodology

This study used quantitative methods to systematically explore the relationship between indoor physical environment and repetitive behavior performance of children with autism spectrum disorder (ASD) in institutional preschool education.Correlation study design is also applied here to study the association between variables without having to manipulate them. This form of design is crucial in identifying the strength and direction of the associations between environmental determinants (e.g., lighting, color, noise level, and spatial arrangement) and classes of repetitive behaviors (motor, vocal, or object-directed behavior) among children with ASD (Walliman, 2017). To analyze such relationships, the study employs the following statistical measures: Pearson Correlation Coefficient to measure the linear relationship between two continuous variables under normal distribution. The measure is most appropriate in the analysis of the direct relationships between some environmental factors and repetitive behaviors (Watkins, 2018); Spearman's Rank Correlation Coefficient- A non-parametric coefficient to apply when data are not presupposed to be normally distributed. It assesses the direction and strength of a relationship between two ranked variables, therefore appropriate for ordinal data or non-linear relationships (Schweinsberg et al., 2021)

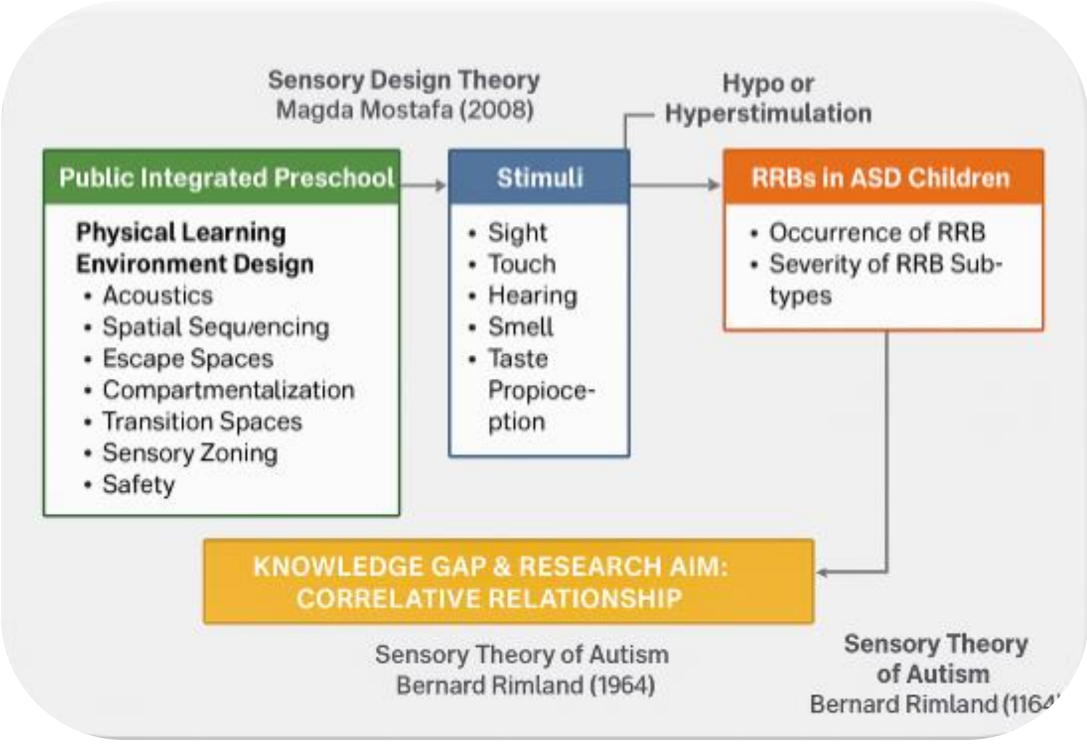


Figure 1. Conceptual Framework (Author's own work with help of Lucid Chart)

Study population

Cluster sampling was employed in the present research to foster logistical efficiency and achieve regional representativeness (Raifman et al., 2022). In Hubei Province, institutional schools for autistic children are not evenly distributed across all cities. Therefore, Yichang city with its high density of such institutions was selected as a representative cluster. Institutional schools in Yichang were treated as clusters, from which a random sample of schools was selected. All the preschool children with ASD in the selected schools made up the sample population. In this manner, it was feasible to carry out in-depth analysis of environmental factors in a geographically accessible space while still allowing findings to portray general institutional practice in Hubei.80 preschool children with ASD took part in the study, distributed in 3 selected institutional schools in Yichang. A 10% buffer was added to the sample size to account for dropouts and data collection inconsistencies.

Table 3 .Sample Size Calculation

Study Phase	Participants (N = 80 preschool children)
	Pilot Study (10% of total sample)	8
Actual Study (90% of total sample)	72

Instrumentation

Data collection process in the study entails the administration of two specific tools, i.e., the Repetitive Behavior Scale-Revised (RBS-R) and the ASPECTSS Design Index. Two research tools will be distributed to different participant groups which include parents and guardians and school staff together with architects and building designers.

RBS-R (Repetitive Behavior Scale-Revised)

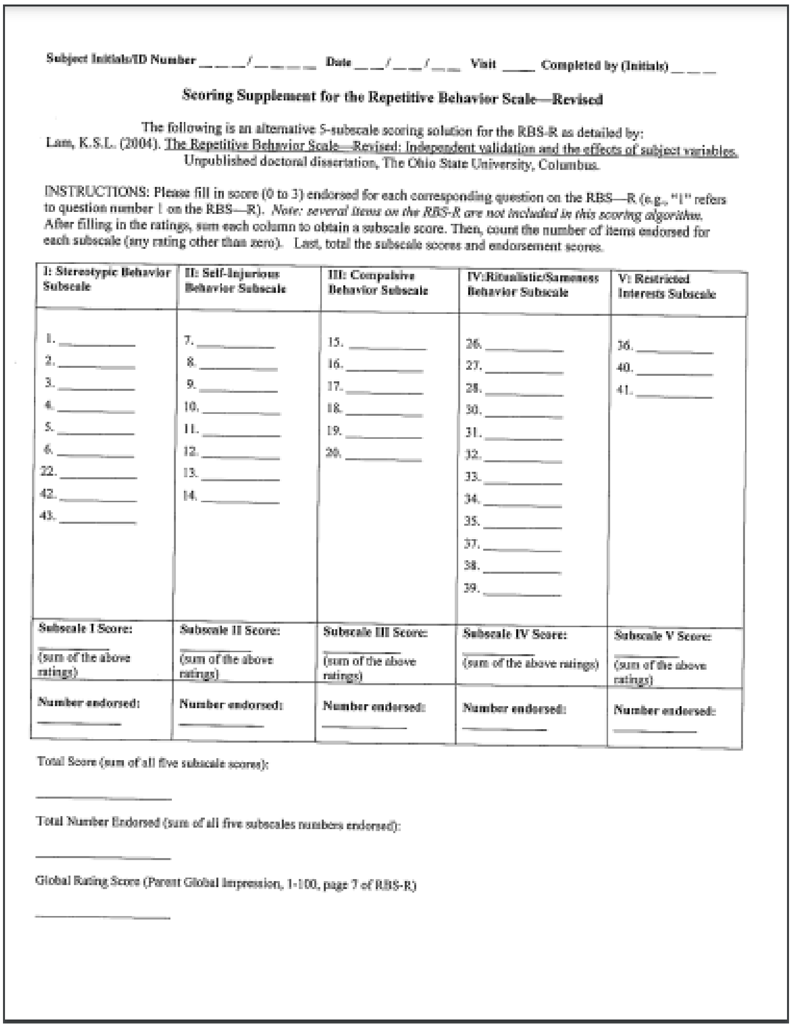
Due to the unique nature of RRBs in childhood ASD, there remains some disagreement on its assessment method (Tian et al., 2022). Most studies on RRBs have used the Revised Autism Diagnostic Scale (ADI-R) (Russell et al., 2019) or the Revised Repetitive Behavior Scale (RBS-R) (Bodfish et al., 2000; Fulceri et al., 2015). The table below compares the common scales.

Table 4. Questionnaire assessment tools for repetitive behavior

Assessment Tool	Year	Main Features	Assessment Content	Applicable Scenarios	Assessment Method
Repetitive Behavior Scale-Revised (RBS-R)	2003	Covers multiple dimensions of repetitive behavior, providing detailed assessment of scope and severity	Stereotyped behavior, compulsive behavior, ritualistic behavior, restricted behavior, self-injurious behavior, excessive interests	Clinical diagnosis, intervention design, and research	Questionnaire completed by parents or caregivers
Repetitive Behavior Questionnaire-3 (RBQ-2)	2012	Simple and efficient, focuses on three main types of repetitive behavior	Stereotyped behavior, ritualistic behavior, restricted behavior	Large-scale screening, rapid diagnosis	Questionnaire completed by parents or caregivers
Autism Diagnostic Interview-Revised (ADI-R)	1994	A structured interview tool covering core features of autism, including repetitive behavior	Stereotyped actions, ritualistic behavior, special interests	Autism diagnosis, comprehensive behavior analysis	Professional interview, answers provided by parents
Autism Diagnostic Observation Schedule (ADOS)	1989 (initial version), 2000 (revised)	Semi-structured behavioral observation, suitable for different ages and language abilities	Stereotyped actions, restricted interests, repetitive behavior, and social impairments	Clinical diagnosis, comprehensive evaluation of autism symptoms	Observation and scoring by professionals
Childhood Autism Rating Scale (CARS)	1980	Assesses the severity of autism symptoms, including repetitive behavior	Stereotyped behavior, restricted interests	Quick assessment of autism severity in clinical practice	Scored by professionals
Aberrant Behavior Checklist (ABC)	1985	Broadly assesses aberrant behavior, with some dimensions related to repetitive behavior	Stereotyped behavior, excitability/impulsivity	Behavioral problem assessment, intervention outcome monitoring	Questionnaire completed by parents or caregivers

For this study,the Repetitive Behavior Scale-Revised (RBS-R) is suitable for assessing the effects of learning environment design on repetitive behavior of children with autism because it provides a comprehensive, standardized, easy-to-use, widely used, adaptable, multi-dimensional assessment and monitoring of changes (Kasari et al., 2021). RBS-R is more suitable for situations where in-depth knowledge of detailed performance of repetitive behaviors across multiple dimensions is required to support comprehensive behavioral analysis or to develop personalized intervention plans (Fletcher-Watson & Happé, 2019). Therefore, when designing a learning environment, RBS-R can help identify the specific type and severity of repetitive behaviors that require intervention, thus guiding how to adjust the environment to reduce adverse effects (Gal & Yirmiya, 2021).

The 44-item Repetitive Behavior Scale-Revised (RBS-R) is a quantitative rating tool used to assess the severity of repetitive behaviors (RRBs) among autism spectrum disorder (ASD) patients. The survey involves six subscales: Ritualistic Behaviors, Compulsive Behaviors, Stereotyped Behaviors, Self-Injurious Behaviors, Sameness Behaviors, and Restricted Behaviors. The caregiver is asked to give an estimate on a 0 (no incidence) to 3 (severe incidence) scale of how many times during the past month each of the target behaviors were noted. Caregivers rate the overall effect of the behavior on a 1 to 100 scale with lower scores indicating no problem and increasing scores indicating increasing severity.



Subject Initials/ID Number ____/_____ Date __/__/__ Visit ____ Completed by (Initials) ___

Scoring Supplement for the Repetitive Behavior Scale—Revised

The following is an alternative 5-subscale scoring solution for the RBS-R as detailed by:
Lam, K.S.L. (2004). The Repetitive Behavior Scale—Revised: Independent validation and the effects of subject variables. Unpublished doctoral dissertation, The Ohio State University, Columbus.

INSTRUCTIONS: Please fill in score (0 to 3) endorsed for each corresponding question on the RBS—R (e.g., "1" refers to question number 1 on the RBS—R). *Note: several items on the RBS-R are not included in this scoring algorithm.* After filling in the ratings, sum each column to obtain a subscale score. Then, count the number of items endorsed for each subscale (any rating other than zero). Last, total the subscale scores and endorsement scores.

I: Stereotypic Behavior Subscale	II: Self-Injurious Behavior Subscale	III: Compulsive Behavior Subscale	IV:Ritualistic/Sameness Behavior Subscale	V: Restricted Interests Subscale
1. ____	7. ____	15. ____	26. ____	36. ____
2. ____	8. ____	16. ____	27. ____	40. ____
3. ____	9. ____	17. ____	28. ____	41. ____
4. ____	10. ____	18. ____	30. ____	
5. ____	11. ____	19. ____	31. ____	
6. ____	12. ____	20. ____	32. ____	
22. ____	13. ____		33. ____	
42. ____	14. ____		34. ____	
43. ____			35. ____	
			37. ____	
			38. ____	
			39. ____	
Subscale I Score: ____ (sum of the above ratings)	**Subscale II Score:** ____ (sum of the above ratings)	**Subscale III Score:** ____ (sum of the above ratings)	**Subscale IV Score:** ____ (sum of the above ratings)	**Subscale V Score:** ____ (sum of the above ratings)
Number endorsed: ____	**Number endorsed:** ____	**Number endorsed:** ____	**Number endorsed:** ____	**Number endorsed:** ____

Total Score (sum of all five subscale scores):

____

Total Number Endorsed (sum of all five subscales numbers endorsed):

____

Global Rating Score (Parent Global Impression, 1-100, page 7 of RBS-R)

____

Figure 2. Repetitive Behaviour Scale-Revised (RBS-R)

ASPECTSS Design Index Survey

Developed by Magda Mostesta (2014), the ASPECTSS Design Index assesses autism-friendliness of built spaces through a set of seven design standards: Acoustics, Space Sequencing, Escape Spaces, Compartmentalization of Space, Sensory Zoning of Transitions, Security Needs, and Predictability. Consisting of 12 questions put forth in these seven parameters, there are five designated for classroom-level assessments and seven to assess at the school level overall. 5-point scale is utilized in the scoring, where 5 represents total compliance with the design specifications and 1 represents zero compliance (Mostafa, 2014). Data on other demographics such as size of student body and teacher-to-pupil ratio shall also be collected. Descriptive explanation of any of the problems of design in the school environment is invited from the respondents. A score of 48/60 or more indicates a high correlation to quality design practice. Mostafa's first survey was conducted in several regions worldwide, with proof of a positive correlation between autism-friendly environments and high-quality design practice (Dong, 2022).

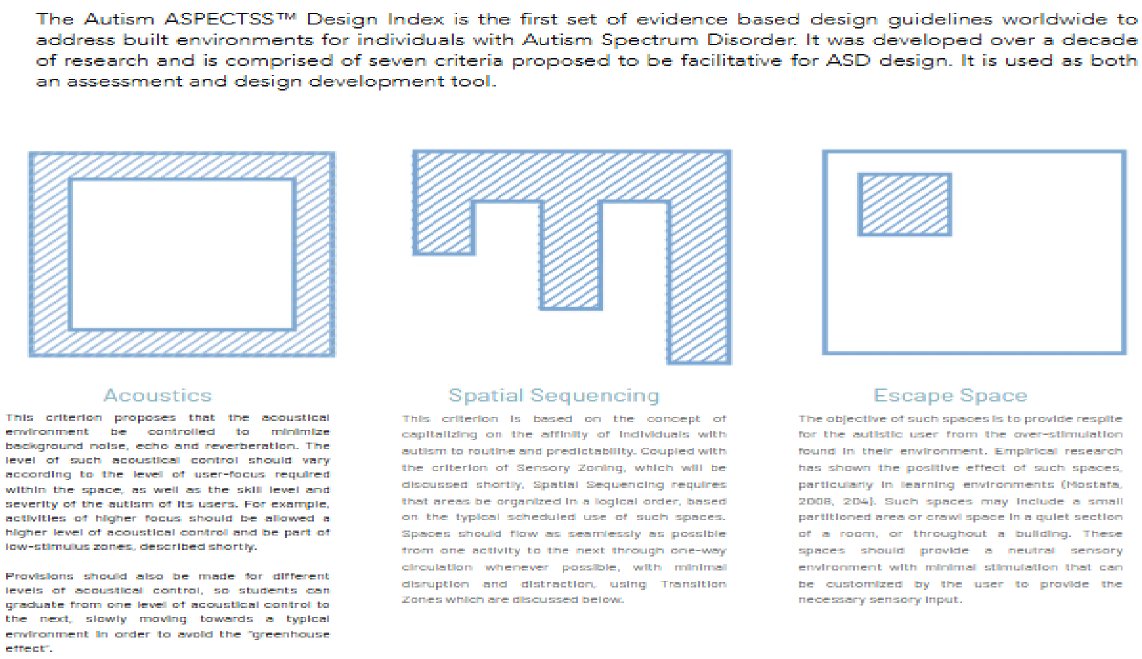


Figure 3. ASPECTSS Design Index Survey

Procedures

Prior to data collection, ethical clearance was obtained from the administrative authorities of respective institutions. This study adheres rigorously to ethical principles, which specifically encompass:

Informed Consent as the ethical cornerstone, ensuring participants are fully apprised of the study's purpose, implications of participation, and the unqualified right to withdraw at any juncture. Parents and legal guardians will receive a comprehensive informed consent document, while educators will be briefed on procedural details via a teacher consent form. Confidentiality and Anonymity are safeguarded through the removal of personal identifiers from collected data, which will be stored in secure repositories accessible exclusively to the research team. Risk Mitigation strategies aim to minimize potential physical or emotional harm. Participants will be notified in advance of the voluntary nature of their involvement and the right to withdraw without penalty should discomfort arise at any stage. Cultural Sensitivity is prioritized within China's preschool education context, with the research team committed to respecting local customs, educational ethos, and normative practices—thereby adapting research instruments to reflect these cultural parameters. Right to Withdrawal is unconditionally guaranteed, enabling participants to discontinue involvement at any time without adverse consequences, thus upholding their autonomy and ethical agency.

The Influence of Physical Environments on ASD Children

The sensory elements within the built environment exert a profound influence on the sensory sensitivities of individuals with Autism Spectrum Disorder (ASD). Studies have shown that soft furnishing materials, such as soothing textures like cork, cotton, and porcelain, can significantly help create a sense of calm for ASD children engaged in indoor learning activities (Norouzi & Garza, 2021). Harmonizing tactile hypersensitivity and hyposensitivity through natural textiles and materials can construct a harmonious and comfortable environment (Clouse et al., 2020). This strategy has been validated effective in children with other sensory impairments, such as deafness and cerebral palsy, enhancing their environmental adaptability and comfort (Ghazali et al., 2019). Choosing wood over metal, flat-woven carpets over linoleum, and balancing maintenance with easy-to-clean requirements (Warman, 2019), as well as adding cushioning areas for sensory training or rest, further enhances environmental adaptability (Warman, 2019; Shaari et al., 2020b). However, existing designs have not specifically addressed Restrictive and Repetitive Behaviors (RRBs) in ASD children during learning, providing an important direction for follow-up research. Although sensory modulation strategies (such as tactile stimulation) can effectively reduce stereotyped behaviors in 60%-70% of ASD cases, they may exacerbate compulsive behaviors (such as handwashing) in individuals with comorbid obsessive tendencies (Gandhi & Lee, 2021). Many scholars emphasize that the impact mechanism of the physical environment on specific behaviors of children with autism still needs in-depth study, as their behavioral problems continue to hinder social integration and quality of life (Clouse et al., 2019; Ghazali et al., 2019; Unwin et al., 2021; Zanoboni & Toftum, 2023).

The Influence of Sensory Aspects (Acoustics)

Acoustics have emerged as a core sensory element influencing the behavior of individuals with Autism Spectrum Disorder (ASD). Studies have confirmed that reducing background noise and optimizing acoustic design—such as using sound-absorbing materials and controlling reverberation time—can significantly mitigate hyperstimulation responses in children with ASD, thereby reducing Restrictive and Repetitive Behaviors (RRBs) (Clouse et al., 2020; Mostafa, 2014). Additionally, among indoor environmental factors, only acoustic and visual designs have been systematically validated to exert significant impacts on ASD behavior. Acoustics play a dominant role by suppressing sudden noises (e.g., the harsh sounds identified by Ueno et al., 2019) and regulating ambient sound levels (e.g., the moderate background noise confirmed by Bellamy et al., 2021), whereas visual interventions (such as dimming systems) alleviate anxiety in 45% of children with ASD (Shaari et al., 2020a), though their direct effects on RRBs require clarification due to conflicting research conclusions. Artificial intelligence (AI) technologies offer innovative pathways for optimizing sensory environments. Through acoustic scene simulation and dynamic lighting adaptation (e.g., the acoustic modeling by Zhu & Li, 2021, and the intelligent lighting systems by Liao et al., 2022), AI can predict and reduce environmental stimuli that trigger RRBs. Real-time adjustments of noise (±5 dB) and light intensity (200–500 lux) have reduced RRB frequency by 30%–40% in preliminary studies (Awaji et al., 2023). However, the impacts of thermal environment and Indoor Air Quality (IAQ) on ASD behavior remain empirically understudied. Although preliminary research suggests that temperatures exceeding 26°C may increase self-injurious behaviors by 15%–20% (Ansara, 2022), causal mechanisms require further validation with physiological monitoring (Zanoboni et al., 2023). In summary, future research should build upon the core role of acoustic design, integrate AI technologies to deepen personalized adaptation of sensory environments, and fill research gaps in thermal environments and IAQ, thereby providing more systematic theoretical support for designing learning spaces for children with ASD.

The Influence of Spatial Sequencing

In addition to sensory design, spatial sequencing is of paramount importance for designers and architects creating environments for individuals with Autism Spectrum Disorder (ASD), who rely heavily on predictability and routine (Mostafa, 2008; 2014). Ghazali et al. (2019) emphasize that spatial sequencing requires the systematic arrangement of areas in accordance with the typical activity schedules of specific spaces. Gaines et al. (2016) propose that ASD-friendly spaces should be characterized by clarity, systematic layout, simple design, safety, comfort, and predictability, with spacious social interaction areas being pivotal in reducing aggressive behaviors during social activities. Flexible layouts that adapt to individual sensory preferences form the core of exploring spatial relationships.

The Influence of Escape Spaces

Individuals with Autism Spectrum Disorder (ASD) are particularly susceptible to sensory overload from environmental stimuli in stressful or unfamiliar settings (Clouse et al., 2019). The concept of "escape space" effectively mitigates overstimulation by providing a secure and calming sanctuary within their proximal environment. Research by Mostafa (2014) has confirmed that access to such tranquil spaces significantly enhances self-regulation in individuals with ASD, enabling them to reintegrate into group activities with teachers and peers after regaining composure.

Escape spaces must be meticulously designed to accommodate diverse sensory preferences, ensuring each space delivers a unique and tailored sensory experience. As synthesized in Vogel's (2008) study, integrating escape spaces into ASD-inclusive educational settings empowers individuals with ASD to control their privacy levels and social interactions. This autonomy not only fosters confidence but also elevates self-esteem.

The establishment of escape spaces is critical for curbing detrimental behaviors in children with ASD, including anxiety, aggression, and physical altercations. Additionally, it holds promise as an intervention to prevent Restrictive and Repetitive Behaviors (RRBs) in indoor learning environments, contributing to the creation of a more supportive and conducive educational atmosphere.

The Influence of Compartmentalisation

Studies have demonstrated that beyond harsh acoustic environments, chaotic spatial configurations can also induce overstimulation responses in individuals with Autism Spectrum Disorder (ASD), underscoring the critical role of effective spatial compartmentalization in indoor learning environments for ASD children as a primary strategy to prevent disruptive behaviors (Mostafa, 2008, 2014). Defined as the systematic organization of architectural spaces based on activity-specific functions, compartmentalization necessitates clear functional demarcation of each zone alongside control over visual stimuli impacting ASD individuals (Mostafa, 2014). Distraction-free spaces with explicit functional signage have been shown to mitigate cognitive disorientation, anxiety, and ambulatory behaviors in ASD children, while prior research confirms that subdividing spaces to align with specialized activities—including storage zones, work areas, and sensory integration spaces—enhances attentional focus (Gaines et al., 2014; Sanchez et al., 2011). Current investigations emphasize the adoption of navigation-facilitating strategies such as color-coded corridors (Gaines et al., 2016) and visual task-step guidelines (Vogel, 2008) to reduce spatial complexity. However, the generalizability of findings is constrained by small sample sizes (median = 65 participants, range 12–92). Notably, while associations between spatial design and symptoms like anxiety and aggression in ASD children have been established, the mechanistic impact of spatial compartmentalization on Restrictive and Repetitive Behaviors (RRBs) remains unexplored. Further research is imperative to clarify the causal relationship between spatial organization and RRB manifestation.

The Influence of Transition Spaces

In Conclusion Transition Spaces play a critical role in facilitating sensory adaptation for individuals with autism during shifts between different sensory stimuli, beyond their function in wayfinding (Ghazali et al., 2019; Mostafa, 2014). Designers can enhance this process by integrating features that enable previews of entrances, exits, and entire spaces, allowing individuals to assess the environment, establish orientation, and adapt more effectively to new settings. Incorporating transitional nodes along spatial pathways promotes interaction, particularly benefiting individuals with autism who face communication challenges. These spaces allow for paced acclimatization to new areas, potentially enhancing self-confidence, reducing anxiety, and fostering social and communication skills (Gaines et al., 2016). Sidelights in corridors enable individuals with autism to preview spaces, boosting confidence and reducing cognitive confusion (Gaines et al., 2016), while reception areas along main corridors foster social connections and alleviate transitional stress for both caregivers and individuals with autism (Gaines et al., 2016; Mostafa, 2014)—interventions that may help mitigate Restrictive and Repetitive Behaviors (RRBs) in children with autism. Decorative floor patterns, such as circular motifs, guide children with autism during activities, aiding spatial orientation (Warman, 2019). Existing research demonstrates that transition spaces significantly influence the behavior of individuals with autism, and leveraging these insights can mitigate RRBs in autistic children while optimizing their learning environments.

The Influence of Sensory Zoning

When engaging in spatial design for individuals with Autism Spectrum Disorder (ASD), architects are required to transcend the conventional model of functional zoning and, instead, establish an adaptive spatial system grounded in the intensity of sensory input (Ghazali et al., 2019; Mostafa, 2014). As an illustration, the design strategy put forward by Clouse et al. (2019) entails the establishment of a calming reception area in the vicinity of a vocational center's entrance, the isolation of high-noise kitchen preparation zones from quiet areas, and the clustering of similar auditory environments. Notwithstanding the confirmation by educators that multi-sensory environments are capable of ameliorating the behavior of ASD children and promoting learning (Unwin et al., 2021), research pertaining to their optimized utilization—particularly with regard to the association with subtypes of Restrictive and Repetitive Behaviors (RRBs) in ASD children—continues to be in short supply. Practical experience has demonstrated that children's autonomous control over the sensory environment constitutes the core mechanism for behavioral improvement, a phenomenon that is congruent with the preference of ASD individuals for environmental predictability (Ashburner et al., 2013; Fujino et al., 2019) and contemporary theoretical frameworks (Palmer et al., 2017; Powell et al., 2016). However, the optimal application paradigm of multi-sensory environments within special education schools still lacks empirical validation (Unwin et al., 2021; 2022).

Multi-sensory environments (MSEs) are a promising approach in ASD-friendly design, reducing RRBs by 25–35% when using user-controlled stimuli (Unwin et al., 2022). Optimal spatial parameters (e.g., 8–12 m²/child) need further validation. Unstructured MSE sessions have shown greater efficacy in reducing stereotyped behaviors than structured ones (Fava & Strauss, 2010), with caregiver involvement enhancing engagement (Hill et al., 2012). Mey et al. (2015) also reported improved sensory functioning in autistic children.

The investigation conducted by Unwin et al. (2022) involving 41 ASD children aged between 4 and 12 years (with a mean age of 8 years) has revealed that the autonomous manipulation of multi-sensory environments can significantly enhance individual attentional focus while reducing indicators of RRBs, including disruptive behaviors, sensory actions, and stereotyped speech. No significant influence, however, was observed on social behavior, anxiety levels, and other such aspects. This finding serves to corroborate the value of autonomous sensory control in the optimization of learning environments, echoing the sensory zoning theory emphasized by Mostafa (2014). Notwithstanding this, the correlation between this strategy and the frequency as well as severity of RRBs in learning contexts necessitates further in-depth investigation.

The Influence of Safety Elements

Safety considerations in physical environment design exert a significant influence on the occurrence of detrimental behaviors among children with Autism Spectrum Disorder (ASD) (Mostafa, 2008; 2014). The installation of security systems at entry and exit points enables teachers to monitor the movement trajectories of ASD individuals, while demarcating boundaries for outdoor areas such as playgrounds provides a sense of safety and order to promote positive behaviors. Additionally, the design of multiple exit routes facilitates rapid evacuation during instances of aggressive behavior (Mostafa, 2014).

Notably, the secure installation of mirrors in restrooms and the design of restrooms that exceed the requirements of the Americans with Disabilities Act (ADA) to accommodate teacher-child interactions not only enriches learning experiences but also ensures safety. Warman (2019) found that configuring windowsills with a depth of 1,300 mm effectively reduces self-inflicted injuries caused by head-butting and mitigates the risk of glass damage. The implementation of gypsum board ceilings at a height of 9 feet or more, combined with the construction of three layers of industrial-grade gypsum board up to 6 feet on interior walls, has been proven to minimize harm resulting from aggressive behaviors among ASD children.

For ASD-friendly learning environments, measures such as selecting sturdy furnishings with rounded edges, regulating water temperature, anchoring furniture, and using window restraints are equally critical. These designs alleviate fear and anxiety among ASD children by enhancing their sense of safety (Gaines et al., 2016; Vogel, 2008), providing empirical evidence for the construction of low-risk, high-support learning spaces.

Opinions and Future Perspectives

Sensory-friendly physical environments show potential for reducing RRB severity and enhancing the quality of life for ASD children. Yet, designing effective interventions demands a deep understanding of how environmental stimuli relate to specific ASD behaviors, especially RRBs.Recognizing environmental-RRB associations is the first step toward evidence-based design, requiring subsequent steps: 1) establishing standardized assessment tools for environmental triggers; 2) conducting controlled trials of design interventions; 3) integrating findings into practice guidelines (Mohd Nazori et al., 2024).Future research should focus on pinpointing triggers and exacerbating factors in learning environments to develop evidence-based design strategies (Trisno et al., 2021).

Conclusions

Early intervention is crucial for reducing the impact of Repetitive and Restrictive Behaviors (RRBs) in children with Autism Spectrum Disorder (ASD). Sensory-friendly physical environments show great potential as effective interventions. Although universal design principles offer a starting point, they often fail to address the specific needs of ASD individuals, especially concerning RRBs.There is a need for further research to clarify the intricate relationship between environmental stimuli and specific ASD behaviors, which can guide evidence-based design solutions. Collaboration among various stakeholders is essential to develop comprehensive guidelines for effectively managing RRBs in learning environments. This paper contributes to the conversation on improving early intervention strategies for childhood ASD, synthesizeing how sensory-friendly physical environments can enhance outcomes for children with RRBs. Physical learning environments have significant potential as early interventions for RRBs in childhood ASD. However, solving this complex issue demands a multidisciplinary approach combining knowledge from psychology, education, architecture, and technology.

References

Abbott, A. E., Linke, A. C., Nair, A., Jahedi, A., Alba, L. A., Keown, C. L., ... & Müller, R. A. (2018). Repetitive behaviours in autism are linked to imbalance of corticostriatal connectivity: a functional connectivity MRI study. Social cognitive and affective neuroscience, 13(1), 32-42.

Abdel Hameed, M., Hassaballah, M., Hosney, M. E., & Alqahtani, A. (2022). [Retracted] An AI-Enabled Internet of Things Based Autism Care System for Improving Cognitive Ability of Children with Autism Spectrum Disorders. Computational Intelligence and Neuroscience, 2022(1), 2247675.

Ansara, M. (2022). The Design of Autism-Friendly Learning Environments: Exploring Flexibility in the Built Environment as a Means to Support the Variability of Individual Manifestations of ASD.

Ashburner, J., Bennett, L., Rodger, S., & Ziviani, J. (2013). Understanding the sensory experiences of young people with autism spectrum disorder: A preliminary investigation. Australian occupational therapy journal.

Awaji, B., Senan, E. M., Olayah, F., Alshari, E. A., Alsulami, M., Abosaq, H. A., ... & Janrao, P. (2023). Hybrid techniques of facial feature image analysis for early detection of autism spectrum disorder based on combined CNN features. Diagnostics, 13(18), 2948.

Balakrishnan, A., Kulkarni, K., Moirangthem, S.,et al. (2019). The rights of persons with disabilities Act 2016: Mental health implications. Indian Journal of Psychological Medicine, 41(2), 119-125.

Barrett, L., Uljarević, M., Jones, R., & Leekam, R. (2018). Assessing subtypes of restricted and repetitive behaviour using the Adult Repetitive Behaviour Questionnaire-2 in autistic adults. Molecular Autism, 1-10.

Bellamy, R., Ring, H., Watson, P., Kemp, A., Munn, G., & Clare, I. C. (2021). The effect of ambient sounds on decision-making and heart rate variability in autism. Autism, 25(8), 2209-2222.

Bodfish, J. W., Symons, F. J., Parker, D. E., & Lewis, M. H. (2000). Varieties of repetitive behaviour in autism: Comparisons to mental retardation. Journal of autism and developmental disorders, 30, 237-243.

Cameron, A., Burns, P., Garner, A., Lau, S., Dixon, R., Pascoe, C., & Szafraniec, M. (2020). Making sense of multi-sensory environments: A scoping review. International Journal of Disability, Development and Education, 67(6), 630-656.

Chahin, S. S., Apple, R. W., Kuo, K. H., & Dickson, C. A. (2020). Autism spectrum disorder: psychological and functional assessment, and behavioral treatment approaches. Translational pediatrics, 9(Suppl 1), S66.

Clark, E., Zhou, Z., & Du, L. (2019). Autism in China: Progress and challenges in addressing the needs of children and families. International Journal of School & Educational Psychology, 7(2), 135-146.

Clouse, J. R. & Rice, F. A. (2020). Designing beyond the Americans with Disabilities Act (ADA): Creating an autism-friendly vocational center. HERD: Health Environments Research & Design Journal.

Creswell, J. W., & Plano-Clark, V. L. (2011). Designing and Conducting Mixed Methods Research (2nd ed.). London Sage Publications Ltd

Doulah, A. B. M. S. U., Rasheduzzaman, M., & Mamun, K. A. (2023). Application of AR Interventions for Children with Autism Spectrum Disorder (ASD): A Systematic Review. Computers, 12(10), 215.

Eissa, N., Al-Houqani, M., Sadeq, A., Ojha, S. K., Sasse, A., & Sadek, B. (2018). Current enlightenment about etiology and pharmacological treatment of autism spectrum disorder. Frontiers in neuroscience, 12, 304.

Erickson, L. C., & Newman, R. S. (2017). Influences of background noise on infants and children. Current directions in psychological science, 26(5), 451-457.

Fan, Y., Chen, J., Shirkey, G., John, R., Wu, S. R., Park, H., & Shao, C. (2016). Applications of structural equation modelling (SEM) in ecological studies: an updated review. Ecological Processes, 5, 1-12.

Fava, L., & Strauss, K. (2010). Multi-sensory rooms: Comparing effects of the Snoezelen and the Stimulus Preference environment on the behaviour of adults with profound mental retardation. Research in developmental disabilities, 31(1), 160-171.

Field. A. (2017). Discovering Statistics Using IMB SPSS Statistics. 5th Edition. SAGE Publications Ltd.

Fujino, J., Tei, S., Itahashi, T., Aoki, Y., Ohta, H., Kubota, M., ... & Takahashi, H. (2019). Need for closure and cognitive flexibility in individuals with autism spectrum disorder: A preliminary study. Psychiatry Research.

Fulceri, F., Narzisi, A., Apicella, F., Balboni, G., Baldini, S., Brocchini, J., ... & Calderoni, S. (2016). Application of the Repetitive Behavior Scale-Revised–Italian version–in preschoolers with autism spectrum disorder. Research in developmental disabilities, 48, 43-52.

Gaines, K., Bourne, A., Pearson, M., & Kleibrink, M. (2016). Designing for autism spectrum disorders. Routledge.

Gandhi, T., & Lee, C. C. (2021). Neural mechanisms underlying repetitive behaviours in rodent models of autism spectrum disorders. Frontiers in cellular neuroscience, 14, 592710.

Ghazali, R., Sakip, S. R. M., & Samsuddin, I. (2019). Sensory Design of Learning Environment for Autism: Architects awareness?. Journal of ASIAN Behavioural Studies, 4(14), 53-62.

Ghazali, R., Sakip, S. R. M., Samsuddin, I., & Samra, H. (2022). Developing a Framework of Sensory Environment for Autism Centre. Environment-Behaviour Proceedings Journal, 7(19), 93-100.

Glod, M., Riby, D. M., & Rodgers, J. (2019). Relationships between sensory processing, repetitive behaviours, anxiety, and intolerance of uncertainty in ASD and Williams syndrome. Autism Research, 12(5), 759-765.

Gulisano, M., Barone, R., Alaimo, S., Ferro, A., Pulvirenti, A., Cirnigliaro, L., ... & Rizzo, R. (2020). Disentangling restrictive and repetitive behaviours and social impairments in children and adolescents with Gilles de la Tourette syndrome and autism spectrum disorder. Brain Sciences, 10(5), 308.

Habbak, A. L. Z., & Khodeir, L. (2023). Multi-sensory interactive interior design for enhancing skills in children with autism. Ain Shams Engineering Journal, 14(8), 102039.

Hill, L., Trusler, K., & Lancioni, G. (2012). Effects of multisensory environments on stereotyped behaviours assessed as maintained by automatic reinforcement. Journal of Applied Research in Intellectual Disabilities.

Isci, B., & Hasirci, D. (2023). Designing Gender-Neutral Playgrounds: The Impact of Natural Environments on Children's Behaviors. Journal of Design and Built Environment, 23(3), 45-66.

Kanakri, S. M., Shepley, M., Varni, J. W., & Tassinary, L. G. (2017). Noise and autism spectrum disorder in children: An exploratory survey. Research in developmental disabilities, 63, 85-94.

Kang, Y. Q., Song, X. R., Wang, G. F., Su, Y. Y., Li, P. Y., & Zhang, X. (2020). Sleep problems influence emotional/behavioral symptoms and repetitive behaviour in preschool-aged children with autism spectrum disorder in the unique social context of China. Frontiers in psychiatry, 11, 273.

Leekam, S, Tandos, J., McConachie, H., Meins, E., Parkinson, K., Wright, C., Turner, M., Arnott, B., Vittorini, L., & Le Couteur, A. (2007). Repetitive behaviours in typically developing 2-year-olds. Journal of Child Psychology and Psychiatry, 48 (11),1131-1138.

Liao, M., Duan, H., & Wang, G. (2022). Application of machine learning techniques to detect the children with autism spectrum disorder. Journal of Healthcare Engineering, 2022(1), 9340027.

Mey, S. C., Cheng, L. M., & Ching, L. W. (2015). The effect of a multisensory program on children with autism. International journal of child development and mental health, 3(2), 36-47.

Mohd Nazori, M. N., binti Ismail, R., binti Rasudin, N. S., binti Mohamed, R., binti Sulli, Z., & do Jayapalan, A. (2024). Mediational Role of Risk Perception in The Relationship Between Vaccination Knowledge and Intention. Clinical Epidemiology and Global Health, 101646.

Mostafa, M. (2014). Architecture for autism: Autism ASPECTSS™ in school design. International Journal of Architectural Research: ArchNet-IJAR, 8(1), 143-158.

Mostafa, M. (2018). Designing for autism: an ASPECTSS™ post-occupancy evaluation of learning environments. Archnet-IJAR: International Journal of Architectural Research, 12(3), 308.

Nair, A. S., Priya, R. S., Rajagopal, P., Pradeepa, C., Senthil, R., et al. (2022). A case study on the effect of light and colours in the built environment on autistic children's behaviour. Frontiers in psychiatry, 13, 1042641.

Narayan, C. L., & John, T. (2017). The Rights of Persons with Disabilities Act, 2016: Does it address the needs of the persons with mental illness and their families. Indian journal of psychiatry, 59(1), 17.

Ng, V., Mari, T. S., & Lin, C. L. (2022). Re-thinking Architecture Education: Conceptualising Curriculum Through the Lens of 21st Century Graduate Attributes. Journal of Design and Built Environment, 22(2), 85-92.

Norouzi, N., & Garza, C. M. (2021). Architecture for children with autism spectrum disorder and their therapists. HERD: Health Environments Research & Design Journal, 14(4), 147-156.

Othman, F. Z., Taib, M. N., Shaari, M. F., & Zaiki, Y. (2023). Potential Application of Brainwaves to Optimise Evacuation Wayfinding Performance During Fires. In 2023 19th IEEE International Colloquium on Signal Processing & Its Applications (CSPA), 190-194

Othman, F. Z., Zaiki, Y., Taib, M. N., & Shaari, M. F. (2023). Hospital evacuation route designs: Impact on brain activity and wayfinding cognition during fire evacuation. In AIP Conference Proceedings, 2881, 1

Palmer, C. J., Lawson, R. P., & Hohwy, J. (2017). Bayesian approaches to autism: Towards volatility, action, and behaviour. Psychological bulletin, 143(5), 521.

Peden, M. E. et al. (2017). Relationship Between Children's Physical Activity, Sedentary Behaviour and Childcare Environment: A Cross Sectional Study, Preventive Medicine Reports, 6, 171-175

Plotnick, R. (2017). Force, flatness and touch without feeling: Thinking historically about haptics and buttons. New Media & Society, 19(10), 1632-1652.

Powell, G., Meredith, Z., & Freeman, T. C. (2016). Bayesian models of individual differences: Combining autistic traits and sensory thresholds to predict motion perception. Psychological science, 27(12), 1562-1572.

Quintana, B., Vikhorev, K., & Adán, A. (2021). Workplace occupant comfort monitoring with a multi-sensory and portable autonomous robot. Building and Environment, 205, 108194.

Russell, K. M., Frost, K. M., & Ingersoll, B. (2019). The relationship between subtypes of repetitive behaviours and anxiety in children with autism spectrum disorder. Research in Autism Spectrum Disorders, 62, 48-54.

Sanchez, P. A., V´azquez, F. S., & Serrano, L. A. (2011). Autism and the built environment. In T. Williams (Ed.), autism spectrum disorders—From genes to environment (pp. 363–380). Rijeka, Croatia: InTech.

Shaari, M. F., Ahmad, S. S., Ismail, I. S., & Zaiki, Y. (2020a). Preschool Physical Environment Design Quality: Addressing Malaysia's PISA Rankings. Asian Journal of Environment-Behaviour Studies, 5(16), 45-57.

Shaari, M. F., Ahmad, S. S., Ismail, I. S., & Zaiki, Y. (2020b). Addressing Recent PISA Rankings: The potential role of preschool physical environment design quality in Malaysia. E-BPJ, 5, 93-99.

Shaari, M. F., Ahmad, S. S., Ismail, I. S., & Zaiki, Y. (2020c). The influence of modified open-plan preschool spaces on cognitive school readiness in Malaysia. Environment-Behaviour Proceedings Journal, 5(15), 123-130.

Shaari, M. F., Zaiki, Y., Ahmad, S. S., & Ismail, I. S. (2021). Modified Open-Plan Preschool Spaces and their Influence on Childrens Cognitive Development. Asian Journal of Environment-Behaviour Studies, 6(18), 47-61.

Shell, S. (2017). Why buildings for autistic people are better for everyone. Forte Building Science Omaha.

Tian, J., Gao, X., & Yang, L. (2022). Repetitive Restricted Behaviors in Autism Spectrum Disorder: From Mechanism to Development of. Current Advances in Neurodevelopmental Disorders: Piecing Together the Candidate Path That Guides the Translation From Aetiology to Treatment.

Tola, G., Talu, V., Congiu, T., Bain, P., & Lindert, J. (2021). Built environment design and people with ASD: A scoping review. International journal of environmental research and public health, 18(6), 3203.
Trisno, R., Lianto, F., & Tishani, N. K. (2021). STEAM Elementary School with the Concept of Creative Learning Space in Heidegger's View. Journal of Design and Built Environment, 21(2), 39-58.
Ueno, K., Noguchi, S., & Takahashi, H. (2019). A field study on the acoustic environment of ASD education classrooms. Building Acoustics, 26(4), 263-274.
UNICEF (2014). International classification of functioning, disability and health: children and youth version: ICF-CY. Accessed on 15 June 2023 from https://apps.who.int/iris/handle/10665/43737
Unwin, K. L., Powell, G., & Jones, C. R. (2021). A sequential mixed-methods approach to exploring the experiences of practitioners who have worked in multi-sensory environments with autistic children. Research in Developmental Disabilities, 118, 104061.
Unwin, K. L., Powell, G., & Jones, C. R. (2022). The use of Multi-Sensory Environments with autistic children: Exploring the effect of having control of sensory changes. Autism, 26(6), 1379-1394.
van der Kruk, Y., Wilson, W. J., Palghat, K., Downing, C., Harper-Hill, K., & Ashburner, J. (2017). Improved signal-to-noise ratio and classroom performance in children with autism spectrum disorder: A systematic review. Review Journal of Autism and Developmental Disorders, 4, 243-253.
Vogel, C. (2008). Classroom design for living and learning with autism. Autism Asperger's Digest.
Wang, H., Hu, X., & Han, Z. R. (2020). Parental stress, involvement, and family quality of life in mothers and fathers of children with autism spectrum disorder in mainland China: A dyadic analysis. Research in Developmental Disabilities, 107, 103791.
Whittaker, J. P. (2019). Tech Giants, Artificial Intelligence and the Future of Journalism. Taylor & Francis.
Yang, R., & Newman, M. W. (2013, September). Learning from a learning thermostat: lessons for intelligent systems for the home. In Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing (pp. 93-102).
Yu, Q., Li, E., Li, L., & Liang, W. (2020). Efficacy of interventions based on applied behaviour analysis for autism spectrum disorder: A meta-analysis. Psychiatry investigation, 17(5), 432.
Zhou, H., Xu, X., Yan, W., Zou, X., Wu, L., & Luo, X. (2020). Prevalence of autism spectrum disorder in China: a nationwide multi-centre population-based study among children aged 6 to 12 years. Neuroscience Bulletin.
Zhao, M., & Fu, W. (2022). The resilience of parents who have children with autism spectrum disorder in China: a social culture perspective. International Journal of Developmental Disabilities, 68(2), 207-218.
Zaiki, Y., & Wong, T. W. (2021). Targeting genetic tool for long non-coding RNA of cancer stem cells with aptamer-guided nanocarriers. Expert Opinion on Drug Delivery, 18(12), 1791-1793.
Zaiki, Y., Lim, L. Y., & Wong, T. W. (2023). Critical material designs for mucus-and mucosa-penetrating oral insulin nanoparticle development. International Materials Reviews, 68(2), 121-139.
Zaiki, Y., Iskandar, A., & Wong, T. W. (2023). Functionalized chitosan for cancer nano drug delivery. Biotechnology Advances, 108200.
Zhu, Y., & Li, N. (2021). Virtual and augmented reality technologies for emergency management in the built environments: A state-of-the-art review. Journal of safety science and resilience, 2(1), 1-10.